W. O. ATWATER MEMORIAL LECTURE

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Nutrition, Stimulation, Mental Development and Learning

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Introduction

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It is especially appropriate, I think, that a lecture honoring one of the pioneers in human nutrition research and education is presented before the XII International Congress of Nutrition. Dr. Atwater would have felt very much at home here, and we are honored and privileged to present the Atwater Lecture before this distinguished audience tonight.

Dr. Wilbur Olin Atwater was responsible for establishing the science of modern human nutrition in the United States, basing much of his work on knowledge and techniques he learned during his travels in Europe. After he obtained his Doctorate under Professor Samuel W. Johnson of Yale in 1869, his interest in Agricultural Chemistry took him to Leipzig and Berlin, and subsequently to Carl Voit's laboratory in Munich. So, from the very beginning, we in the United States were party to international cooperation in food and nutrition studies—the kind of cooperation that we see exemplified at this congress of scientists, physicians, educators, and public health administrators from throughout the world.

Dr. Atwater's work in the late 19th Century provided a rich legacy for modern human nutrition research. The basic units of energy values for carbohydrates, fat and protein developed by Atwater remain the standards in use today. He studied nutrient losses resulting from processing and cooking. He made pioneering food consumption surveys in various geographic areas and among differing ethnic and socio-economic groups. He was particularly concerned with the problem of nutrition of the poor, the disadvantaged, institutionalized inmates, and others in unfortunate circumstances.

His research in food composition, processing, consumption, and nutrient requirements anticipated some of our current work in the United States Department of Agriculture—our Nutrient Data Bank, our present nationwide food consumption surveys, and our current research on the metabolism of trace minerals and on the effects of dietary fats on body functions.

Dr. Atwater's accomplishments in human nutrition research were so significant that the Agricultural Research Service felt it was appropriate to create a lecture in his honor. So, in 1963, we began the lecture series bearing Atwater's name—to honor the memory of an extraordinarily gifted scientist and deeply concerned human being—and to call attention to individuals who have contributed in outstanding ways to our knowledge of human nutrition.

Today's address—the thirteenth in the series of Atwater lectures—is by Dr. Joaquin Cravioto, Professor of Pediatrics and Scientific Director of the National Institute for Children's Health Sciences and Technology in Mexico City. Dr. Cravioto is an internationally known researcher in child nutrition, and he was one of the pioneers who characterized infant malnutrition.

The contemporary interest concerning the relationships between child malnutrition and intellectual development and behavior stems

from his original pioneer work and concepts. Over the past two decades, he has addressed these important questions:

- How can we measure and evaluate child development and behavior?
- What is the relationship between economic, social, familial, and educational factors in child development?
- And how do we intervene in these relationships in ways that are feasible and useful?

These are continuing problems of paramount importance throughout the world.

The first references in his extensive bibliography referring to psychological and social factors are dated in the very early 1960's. He has led the field since that time, and is a leader and pioneer within his country and the United States, and, in fact, throughout the world.

Dr. Cravioto has received numerous distinctions including the National Award of the Mexican Academy for Scientific Research, national awards in pediatrics and public health, and the Gold Medal of the Indian Nutrition Society. He is a member of the Swedish Royal Society of Sciences, the Mexican National Academy of Medicine, the National Academy of Pediatrics, and the National Academy of Sciences, and a founding member of the Mexican Society of Nutrition and the Mexican Society of Biochemistry.

Dr. Cravioto earned his M.D. from the Army Medical School of Mexico and a Master's Degree in Public Health from the School of Public Health and Hygiene in Mexico.

He is author of more than 200 publications on the diagnosis and prevention of infantile malnutrition, and on the effects of malnutrition on mental development, learning, and behavior.

Dr. Cravioto is a scientist, a humanist, and an educator of outstanding accomplishment. The title of his lecture this evening is "Nutrition, Stimulation, Mental Development and Learning."

Nutrition, Stimulation, Mental Development and Learning

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If we believe that the ultimate goal of the research scientist is to increase the pool of knowledge that will make man less vulnerable to the forces of nature and give him a better chance of thriving in a universe where the ignorance of its laws can cause him irreparable damage, then one automatically accepts that knowledge should be transformed into socially relevant technology and this technology must reach the beneficiaries.

Wilber Olin Atwater fulfilled this ultimate aim. Starting with his doctoral dissertation on the chemical composition of some varieties of American corn, he increased our knowledge of the energy content of food, directed the first Agricultural Experimental Station linking the farm problems to scientific research solutions, and, in the last years of his life, was concerned with the need of a worldwide epidemiological study of the relationships among diet, labor performance and health.

I am very grateful for the great honor of being asked to deliver this Memorial Lecture and through it pay my respects to Wilbur Olin Atwater, a man devoted to bettering man's well-being through science and its application to daily life problems, such as food, feeding and health.

In the second half of the twentieth century, there has been an increasing interest in the ways through which environment can affect man. Health, growth and development have become a major topic of interest for an increasing number of persons and institutions dealing with social, political and economic policies. This, in turn, has led to the consideration of unfavorable environment as an important factor in the life of the individual from the time of conception to socially functioning adulthood.

Among the many features of the child's environment, adequate nutrition has been accepted as a prerequisite for optimal growth and development. Nowadays, nobody denies that a diet adequate in quantity and quality is an essential, and perhaps, the most ubiquitous factor affecting man's growth, health and development.

At first appearance, nutrition is primarily related to physical environmental factors such as climate, weather, topography and geological structure, and to the biological component of human environment represented mainly by its food chains; however, the primordial determinant of the nutritional status of a population is the social environment.

Malnutrition at the community level is a man-made disorder characteristic of the underprivileged segments of society. This is particularly true of the pre-industrial societies, characterized by a social system which consciously or unconsciously creates malnourished individuals generation after generation through a series of social mechanisms such as limited access to goods and services, limited social mobility and restricted experiential opportunities at crucial points in life.

The understanding of malnutrition in man thus requires an ecological frame of reference in which the social, psychological and cultural aspects of human behavior are appropriately related to the biological nature of man and to the physical environment in which he lives. Nutrition is above all an important focus on organized human behavior.

Nutritional inadequacy in pre-industrial societies and in underprivileged segments of affluent societies is manifested by a series of disease states, which, although usually affecting a large proportion of those populations, are particularly prevalent in the vulnerable groups: infants, young children and pregnant and lactating women. This is due to the influence of the social milieu on individuals whose physiological requirements for nutrients are the highest.

In the fight against malnutrition, survival was a primary concern. Better knowledge of the difference in homeostatic responses to noxious agents in well-nourished and malnourished children, a more detailed knowledge of the biochemical pathology of malnutrition[1]; together with better means for the prompt diagnosis and treatment of electrolyte disturbances and infections played a major role in reducing lethality. The prognosis for survival of severely malnourished children treated in pediatric wards has improved from 50 percent to 95 percent.[2] In spite of these advances, the problem of severe malnutrition in infants and children was not eliminated when a low lethality rate had been achieved. Since the majority of malnourished children would survive and since in vast regions of the world the majority of living adults have experienced at least one episode of malnutrition in childhood, we recognized the need to consider the possible consequences of early malnutrition on later mental development and learning.

Rather than starting with the question of the impairment of mechanisms of brain functioning which may result from deficient nutrient intake, our strategy was to determine whether the more readily noted reductions in somatic growth and biochemical development were associated with reduced mental performance.[3-5] If mental lags were found, then we would try to document whether they represented permanent changes in functional effectiveness or were merely transient phenomena. This approach was based on the assumption that a negative finding would indicate that the lower performance found in malnutrition was a transient phenomenon which disappeared with nutritional rehabilitation. On the other hand, if after successful dietary treatment the children still exhibited significant lags in learning and behavior, the implications for policy making and national economic planning would be of such an importance that a systematic investigation should be initiated in order to define, the causal relationship between malnutrition and mental development, and the interaction of deficient nutrient intake with other adverse social, cultural and educational circumstances affecting the child. Inadequate nutrition, except under highly special conditions such as those of war or of natural catastrophe, is a characteristic of children living under conditions of social, cultural and stimuli deprivation.

Studies of mental performance of patients with kwashiorkor during the period of rehabilitation have shown that as children recover from malnutrition, developmental quotients increase in most cases. The magnitude of the increment was in direct relation to the age at which the children suffered the disease. Therefore, with successful treatment, the difference between chronological and mental age progressively diminished in all children except in those who were stricken by severe malnutrition at less less than six months of age.[6-8] (Figures 1 and 2).

Research conducted on infants recovering from nutritional marasmus also has disclosed that basal intelligence and psychomotor activity, as judged by the Bayley Scales,[9] remain severely retarded despite apparent somatic recovery. These studies extend the results found in children recovered from kwashiorkor and point out that both extremes of chronically severe protein-calorie malnutrition behave in a similar way, giving marked retardation in mental development which is present even after physical and biochemical rehabilitation.

The association between malnutrition in preschool children and low levels of mental performance has been amply documented in several regions of the world where malnutrition is prevalent. A direct association between deficits in height and weight of severely malnourished children and retardation in psychomotor, adaptive, language and social-personal behavior has been reported from several countries.[10-16]

Another approach being followed in the assessment of the later effects of malnutrition has been the study of survivors several years after discharge from the hospital. Two main strategies have been used for this purpose. The first

Figure 1

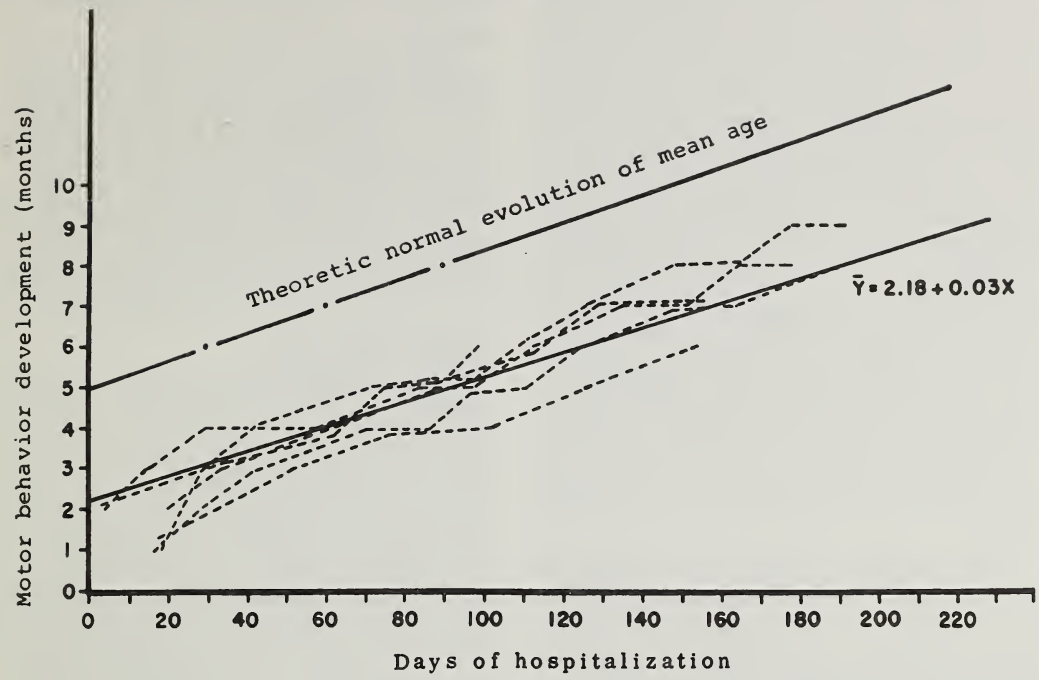
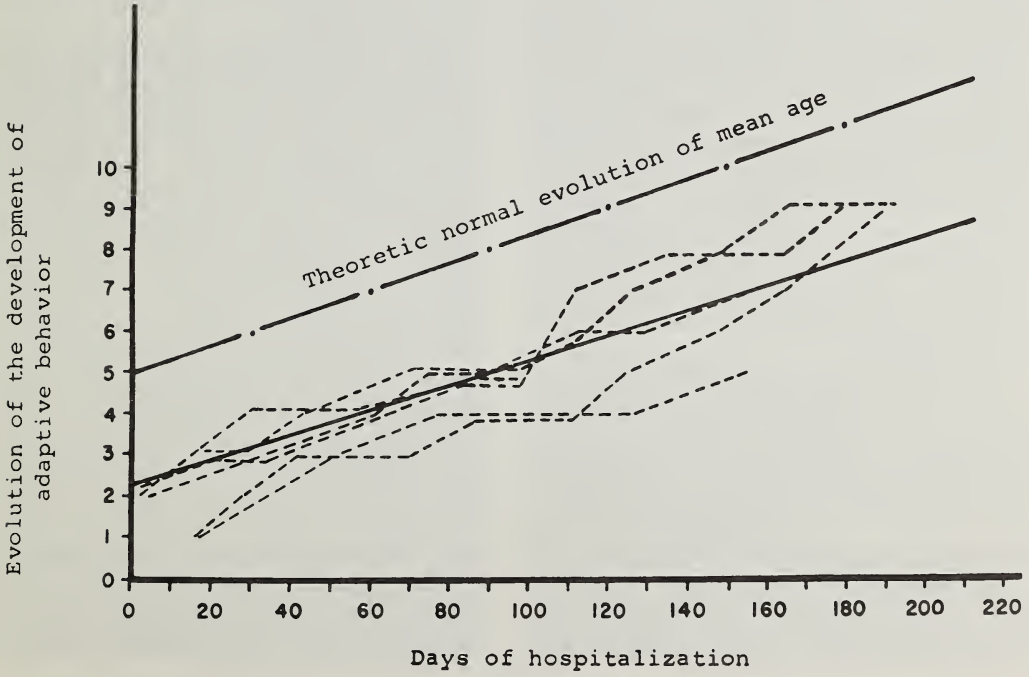


Figure 2



one compares the mental performance of children with documented past histories of severe malnutrition with the mental performance of children living in the same community, but without the antecedent of severe malnutrition. Since all investigators are well aware that severely malnourished children live in environments conducive, in many ways, to lower intellectual performance, they have tried to match index cases with comparison children for those variables considered as capable of playing an important role. The second strategy involves the use of siblings as controls. The assumption behind this type of research design is that siblings as controls cancel out the majority of the demographic or macroenvironmental factors leaving those related to the specific microenvironment of each child within his own family to be accounted for by other means or in another study.

Seven studies employing the first strategy and two studies using siblings as controls have been published in the available literature. These reports deal with children living in quite different cultural settings with geographical representations for Europe, Asia, Africa, the Caribbean, and Latin America.[17-25]

The results of all these studies show that the environment in which children at risk of malnutrition live, is highly negative in its effects on mental development. Regardless of the presence or absence of a previous admission to a hospital because of severe malnutrition, children developing in this milieu have a high probability of showing poor performance on intelligence testing. The presence of a superimposed episode of malnutrition occurring early in life, with enough severity to force the child into a hospital, increases his chances of scoring values even lower than those characteristic of his social class.

In spite of the methodological errors found in many of these studies with regard to sample size, psychological tests employed and lack of documented nutritional history, it is clear that, even after a period of several years, children who have been successfully treated for severe malnutrition and are considered as cured, still show developmental lags. These occur not only in motor behavior, but in several other areas which include hearing and speech, socio-personal behavior, problem solving ability, eye-hand coordination and categorization behavior.

With the demonstration that survivors of malnutrition perform at a lower level than either children of the same ethnic and socioeconomic class or siblings, we had to consider the degree to which this handicap represents permanent changes in the child's capacity or whether the negative outcomes are reversed by appropriate modification of other non-nutritional factors present in the environment of the child.

Research Strategies

Because of the initmate association between nutritional status and socioeconomic level in almost all societies, children who have been at greatest and most persistent nutritional risk tend to cluster most heavily in the lowest social and economic segments. Such segments of any population differ from the remainder not only in their increased exposure to nutritional stress but also in a host of other variables. They tend to have poorer housing, higher infection rates, lower levels of educational accomplishment, greater degrees of attachment to outmoded patterns of child care, and in general to live in circumstances which are less conductive for the development of technologic and educational competence.

Given these facts and associations, it is inevitable that any consequences for physical or mental growth deriving from nutritional conditions of risk will be associated with social status and the variables related to it. There has been some tendency to view this relationship circularly and to conclude that social status per se is capable of accounting for the disturbed outcomes in development. This is unfortunate, since it substitutes a truism for an analysis. Given the associations between depressed social standing and undesirable physical and mental outcomes, the task of analysis is to determine the effective variables which mediate these outcomes. Clearly, social class, as such, does not determine physical stature. Rather, individuals are stunted when their social positions provide a general environment in terms of nutrition, infection, habits and housing which influence the biologic processes involved in growing. Similarly, mental growth is modified to

the degree to which conditions of life associated with depressed social position function directly, to modify the growth and differentiation of the central nervous system, and indirectly, to affect the opportunities for obtaining and the motives for profiting from experience.

The strategies with which investigators have approached the study on the effect of malnutrition on development were derived in the first place from the investigators' views of human malnutrition. One group has been dominated by certain aspects of the Indian experience and has considered malnutrition an acute disorder of severe degree more or less sharply delimited in time. Another attitude views malnutrition as a chronic state, which may or may not have acute exacerbations, related both to social conditions and to the age and physiologic stage of the individuals at risk. Increasingly, it has come to be recognized that, except under highly unusual conditions such as those of war or of natural catastrophe, the major problem of human malnutrition is chronic with occasional acute exacerbation.

Three complementary approaches have been taken to elucidate causal factors and consequences associated with the most prevalent variety of human malnutrition. In each of these approaches there has been general agreement that the young organism should be the focus of study, both because of transiency of consequences attaching to even severe degrees of malnutrition in adults and because of the various findings on the vulnerability of the young brain even to mild dietary restrictions. Against this general agreement on focus, the three major strategies of research have been the deprivation model, the intervention model and the natural history or ecologic model. Investigations within any of these frameworks have included cases studies, the comparison of populations, and the analysis of special conditions of risk and of replacement and rehabilitation.

Animal investigations have, for the most part, taken place within the framework of deprivation models. Experimental animals have been used, not so much to replicate the most common human conditions of chronic and moderate deprivation, but rather, to examine the effects of severe degrees of food deprivation similar to that found under episodic famine conditions. Animals have been nutritionally deprived both in a qualitative and quantitative sense and the effects of such nutritional lacks upon growth and development have been reported. These studies in their totality provided clear evidence for at least three developmental consequences of severe malnutrition. In the first place, animals exposed to the experimental conditions, particularly when exposure had occurred early in life, exhibited growth failures which were not fully repaired by a subsequent presentation of an adequate diet, even when this was accompanied by supplementations. Second, such early severe malnutrition resulted in maturation lags accompanied by the development of abnormal metabolic and enzymatic patterns. Third, in almost all instances in which behavior as well as central nervous system structure and composition have been carefully studied, the exposure of the animal to malnutrition has resulted in central nervous system abnormality and some degree of behavioral incompetence.

The animal studies based upon the deprivation model have been extremely valuable. They have permitted an examination of the effects of malnutrition upon the biology of the organism under controlled conditions which would be impossible and immoral to study with human subjects. They have provided data about organs, systems and mechanisms of biological organization which risk the most damage when exposed to malnutrition. The animal studies, however, have not provided a complete analogy to the human condition for several reasons. First, the organisms studied have no social substrate against which human nutritional deprivation takes place and with which it interacts. Second, the effects on behavior have necessarily been limited to the simple types of behavioral adaptation of which the lower animal is capable. Therefore, the effects of malnutrition on complex behavioral and social functions could not be studied. The analogy, though useful, is incomplete and a complement to rather than a substitute for the study of the effects of malnutrition in man.

The interventionist approach represents the other side of the deprivation coin. Through its use, the investigator wishes to assess the conjoined effects of nutrition, infection, and familial

and social circumstances by systematically altering each of the relevant variables. In practice, this has meant the differential application of food supplementation, infectious disease control, improved housing, education, economic support and increased opportunities for social learning in presumably equated communities or population samples. The method apparently separates influential variables and cross-compares then in a manner similar to that used in the standard experiment. The similarity, however, is perhaps more formal than real. It is extremely difficult to achieve comparability of groups and to prevent effects spreading when subsections of a single population are being differentially supplemented. Moreover, each time a single variable is affected, the danger of ecologic rearrangement exists.

Moral problems, too, surround the use of food supplementation in studies based upon the intervention model. Perhaps the principal problem is the recognition that such supplementation will, in most instances, be terminated at the end of the period of study. The effect of the supplementations on food ecology and the potentially disastrous consequences of termination cannot be viewed lightly. Such a consideration, however, is clearly moral rather than methodological.

The crux of the methodologic problem in supplementation models is the comparability of the groups to be differentially treated. It must be recognized that to ensure comparability, particularly when a multiply caused phenomenon is being considered, one must first carry out a detailed ecologic analysis of the groups to be studied. It may be argued, therefore, that such an analysis may, in itself, be an adequate basis for the identification of determinative variables, if sufficient natural intragroup variability exists to permit systematic internal cross comparisons. This set of considerations lead to the second major approach-ecology. We believe this approach is the first essential form of study and we have used it in our longitudinal investigation in "the Land of the White Dust".

The ecologic approach is a particular form of the natural history method. It seeks to determine the nature of effective variables through a consideration of their interrelations in a single population. When applied to the problem of malnutrition, it attempts to filter out patterns of cause and consequence by considering the interrelations among food, health and social factors. By orienting itself longitudinally, the ecologic approach can identify age-specific conditions of risk, relate antecedents to consequences at different developmental stages, and integrate biologic and social time scales. It can consider both the general and the microenvironment of the developing individual and deal with the interaction of biologic and social variables. Perhaps most important for its usefulness is the fact that it uses uncontrolled variation as the fact of study. A basic requirement for the use of the ecologic method is, therefore, sufficient variation in the attributes to be considered in the population studied. If such variation is present, associative analysis can serve to identify, to segregate, and to interrelate the influential factors that affect the consequences with which one is concerned.

Transient or Permanent Sequelae

In the attempt to determine whether the mental lags present in survivors of early malnutriton are or could be reversible, we started our analysis contrasting a series of macro-environmental features present in a group of children who developed clinically severe protein-calorie malnutrition against a group of children selected from the same birth cohort who were never diagnosed as severely malnourished and who were matched at birth with the malnourished for sex, gestational age, season of birth, body weight, total body length and sensorimotor performance.[26]

It seems important to emphasize that cases of severe clinical malnutrition occurred despite the fact that all children in the cohort were medically examined every two weeks. Those who failed to grow normally were identified, their infectious illnesses were treated, and their parents were given advice (which they did not follow) on the appropriate feeding and management of children who fail to thrive. In contrast to its lack of influence on the incidence of clinically severe malnutrition, this medical attention decreased the infant mortality rate from a figure of 96 per thousand to 46 per thousand, and also reduced the preschool mortality of the cohort by one-half. These data point out once again

that traditional medical care can strongly influence mortality while having minimal or no effect on morbidity.

The factors of the macroenvironment considered related first, to the parents as biological and social organisms, second, to the family structure and thirdly, to objective circumstances, such as source of family income, income per capita and sanitary facilities available in the household.

Differences in age, weight or height of the parents, differences in the number of pregnancies or in the number of live children were not significant enough to distinguish the families of the controls from the families of the future malnourished children. No significant associations were found between the presence or absence of clinical advanced malnutrition or in the variables related to personal cleanliness, literacy or formal education of the father or the mother. Neither the size of the family nor its type (nuclear or extended) were factors that could separate the homes of malnourished children from those of the controls without malnutrition.

The socioeconomic status of the families was estimated through the use of four indicators: principal source of family income, sanitary facilities present in the home, annual per capita income and percentage of total expenditures used for food. None of these four indicators was significantly associated with the presence or absence of children with advanced malnutrition in the family.

Contact with mass media was explored through radio listening and, in literate parents, through newspaper reading. The number of mothers or fathers of malnourished children who were regular newspaper readers was not significantly different from the number in the matched control group. Similarly, the number of fathers who listened regularly to the radio was similar in both the malnourished group and the control group. In contrast, although a nearly equal number of mothers were radio listeners and non-listeners in the malnourished group, there were three times as many radio listeners as non-listeners in the matched control group. The difference was significant at the 0.05 level of statistical confidence.

In summary, from all features of the macroenvironment the only differential between severely malnourished children and controls matched at birth for gestational age, body weight and total body length was the mother's contact with the world outside the village through regular radio listening. None of the other characteristics of the parents (biological, social or cultural) nor of family circumstances (including per capita income, main source of income and family size) was significantly associated with the presence or absence of severe malnourishment.

Because of the lack of association between the features of the macroenvironment and the presence of severe malnutrition, attention was directed toward the analysis of the microenvironment of the two groups of children. The potential for stimulation in the home as a general indicator of the quality of child care, and the mother's psychological characteristics as the principal stimulating agent for the child, were selected as the focus of the analysis. The instrument used for estimating home stimulation was the inventory developed by Caldwell[27] and designed to sample certain aspects of the quantity and/or quality of social, emotional and cognitive stimulation available to a young child within his home. The maternal transactions with her child were recorded and scored by an adaptation of the Maternal Behavior Profile developed by Nancy Bayley, Laboratory of Psychology, National Institute of Mental Health. The profile contains 20 variables comprising the majority of transactions occurring during a test situation. Each variable consists of seven scaled steps, each designating a relative point of degree or type of manifestation of that variable. Each step is defined as a statement of behavior. The statement that most closely portrayed the reaction of the mother, as her habitual response during the first 12 consecutive monthly examinations, was taken as her rating on that particular aspect of behavior.

When the group of severely malnourished children was compared with the control group, it was evident that even before the appearance of the first case of severe malnutrition, available home stimulation scores were markedly different. Thus, at six months of age, on a range of 27 to 41 scoring points, one of every four "future malnourished" children had 30 or fewer points and none scored higher than 36 points.

None of the control children had a home with a score of less than 32 points, and at least one of every four homes scored above 36 points. Similarly, at 58 months of age, when the malnourished children had been rehabilitated, in a range of scores from 55 to 124, almost one-half of the survivors of severe malnutrition were in homes with scores below 104 points and one fourth of their homes did not exceed 84 points. As a contrast, the homes of the control children had a minimum of 100 points, with almost one-half above 110 points.

The behavioral responses of mothers of infants who later developed severe malnutrition also differed from the responses observed in the mothers of the control children.[28] The highest levels of statistically significant difference between the two groups were observed in the mother's response to the interview; and in the mother's behavior when, in a test situation, her child performed adequately and easily, and in her overt signs of sensitivity toward her child.

Significant differences also were observed for: interest in the child's performance, response to the child's needs, the mother's view of her role in the test situation and the emotional involvement of the mother with her child ($p < 0.01$). The amount of verbal communication and the expressions of affection toward the child showed differences between the two groups at the 0.02 level of statistical confidence. The mother's reaction when her child performed extremely well, her status consciousness and her cooperation with the examiner during the test gave differences in behavioral responses significant at the 0.05 level. A significance level of 0.10 or less was obtained from the test group and the control group for the mother's behavioral responses when the child had difficulty with a test item, her affective response to the entire situation, and her control of the child during the test (Table 1).

The amount of physical contact with the child, mother's overall general evaluation of the child, tolerance of the child's behavior, type of physical contact with the child and hostility toward the child were the five aspects of behavior during the test situation in which responses from mothers of malnourished children and control children did not show statistically significant differences even at the 0.10 level of confidence (Table 2).

TABLE 1

ASPECTS OF TEST SITUATION TO WHICH MOTHERS OF "FUTURE" SEVERELY MALNOURISHED CHILDREN AND OF CONTROLS DID NOT SHOW SIGNIFICANTLY DIFFERENT BEHAVIORAL RESPONSES. ("LAND OF THE WHITE DUST")

ASPECT OF TEST SITUATION	"t" Test (SEPARATED)	p
Reaction when child performs easily	4.03	0.000
Response to interview	3.61	0.001
Sensitivity to child	3.51	0.001
Interest in child's test performance	3.19	0.003
Responses to child's needs	3.09	0.004
Mother's view of her role	2.92	0.006
Emotional involvement with child	2.79	0.009
Amount of verbal communication with child	2.57	0.015
Expressions of affection toward child	2.54	0.016
Reaction when child performs extremely well	2.33	0.027
Status consciousness	2.18	0.036
Cooperation with examiner during testing	2.11	0.042

TABLE 2

ASPECTS OF TEST SITUATION TO WHICH MOTHERS OF "FUTURE" SEVERELY MALNOURISHED CHILDREN AND OF CONTROLS DID NOT SHOW SIGNIFICANTLY DIFFERENT BEHAVIORAL RESPONSES. ("LAND OF THE WHITE DUST")

ASPECT OF TEST SITUATION	"t" Test (SEPARATED)	p
Reaction when child had difficulty on an item	1.81	0.079
Mother's affective response to entire situation	1.74	0.092
Control of child during test situation	1.70	0.098
Amount of physical contact with child	1.59	0.121
Mother's overall general evaluation of child	1.34	0.192
Tolerance of child's behavior	1.14	0.262
Type of physical contact with child	0.34	0.736

Srikantia and Sastry[29] have shown that mothers of children with or without kwashiorkor, even when matched for most variables (such as age, parity, family size, income, religion, caste, urban or rural, etc.) differ not only in specific knowledge of food values for children, concepts regarding weaning practices and timing of supplementary foods, but also in their attitudes on general health care and in their concern for their child's health. The mothers of children with kwashiorkor also performed at a lower level on a battery of intelligence tests. Martinez et al.[30] also found a low level of measured intelligence in a group of mothers of severely malnourished children in Mexico.

A study conducted in a pre-industrial bilingual village of Guatemala,[31] indicated that in addition to radio listening by the mother, the language spoken to the child at home could separate infants with significantly different weight increments in the first six months of their lives. Mothers who addressed their children in the local dialect of the village had infants whose weight increments were significantly lower than the increments of infants whose mothers talked to them in the national language.

A logical hypothesis is that the mother's radio-listening habits and the use of the national language in preference to the local dialect are indicators of a behavioral pattern breaking away from the traditional. This kind of mother may take more chances at innovative ideas, provide her child with a more diversified and stimulating home environment, and view her maternal role as a continous series of affective, engaging and gratifying transactions with her child and not simply as one of passive traditional status.

It becomes clear that the features of the poor microenvironment of the potentially malnourished child capable of influencing mental growth and development are a low level of home stimulation and a passive traditional mother who is unaware of the cognitive needs of her child and responds to him in a minimal way.

It has been correctly stated that in most studies dealing with mother-child interactions, a model evaluating the influence of the mother's behavior on the child, but not the influence of the child's behavior on the mother, has been implicitly or explicitly employed.[32] Pollitt[33] has emphasized the discussion of a multifactorial etiology of malnutrition, pointing-out that the study of the host is generally superficial and segmented. The danger of this unidirectional focusing is the lack of capacity to judge the possibility that the socializing behavior of the parents could be partially dependent on the temperamental or constitutional characteristics of the child as has been described by Bell and others.[34-36]

In our studies, an analysis of the scales employed shows that our interest is in the mother's behavior during a situation created by the testing of her child. In other words, we wish to analyze the reaction of the mother confronted with a variation in a reactive stimulus (for example, when changing the efficiency with which her child performs something that is asked of him; the reaction of the mother towards the changing necessities of her child during the test; her cooperation with the examiner to evaluate whether her behavior is dependent on the stimulus or whether it constitutes a pattern of behavior that is only slightly dependent on a specific stimulus, as seem to be the case with our group of low socioeconomic rural mothers).

In the interpretation of the data presented it is interesting that the level of attention, the ease with which the children became interested in the way the different stimuli were handled during the test, and their somatometric measurements were not different at birth in the two groups examined[37] nor at any other age before the appearance of malnutrition, just as there were no differences between these groups and the cohort as a whole.

It must be remembered that in the studies reported here we are referring to clinically severe malnutrition which appeared, with one exception, during the second and third years of life. Even the cases of marasmus were diagnosed after the children were one year old.

In marasmic cases of the "Monckeberg type" (that is, small infants who at four to six months of age have practically the same body measurements that they had at birth), it is possible that certain maternal attributes, such as age, multiparity, short spacing pregnancies and certain characteristics of the child such as low birth weight, early weaning, immature suction be-

havior and lethargy, could be significantly associated with marasmus. At other ages these associations are not apparent and children show no differences in behavior as long as they are not malnourished. Contrary to this, the behavior of the mother towards the child and other characteristics of the microenvironment showed significant differences even before the time of appearance of severe malnutrition. It is not surprising that dealing with diseases of children, at a certain age the characteristics of the host are the most important, while at another age the characteristics of the environment may play a major role in the development of the disease.

Within the context of the lower level of available stimulation in families having children with severe clinical malnutrition, the studies of Viteri on the effect of physical inactivity on growth retardation of young rats,[38] and a review of some important dimensions of food and feeding in human children appear as relevant.

Weaned 21-day-old Wistar rats either were restricted in their physical activity or were allowed free movement as well as being forced to walk in a roller drum. All the animals were fed a commercial stock diet, first ad libitum and then on successive experiments in amounts equivalent to 73 percent, 49 percent, and 33 percent of the dietary intake of a group of rats that was neither restricted in physical activity nor forced to do extra exercise.

The results obtained in regard to food utilization as a function of physical activity are shown in Table 3. As may be seen, the mean efficiency of food utilization expressed as grams of food per gram of gained body weight in a time period of 32 days was significantly higher in the active animals. The data show that at all levels of intake studied, physical inactivity reduced the efficiency of food utilization. The greatest difference between the inactive and active groups was present at food intakes equivalent to 73 percent and 49 percent of normal.

TABLE 3

EFFICIENCY OF FOOD UTILIZATION BY NORMAL, INACTIVE AND ACTIVE RATS FED ON ADEQUATE DIET EITHER "ad libitum" OR IN RESTRICTED QUANTITIES.

FOOD INTAKE	GROUPS	EFFICIENCY OF FOOD UTILIZATION (g. OF FOOD INTAKE PER g. OF WEIGHT GAIN IN 32 DAYS)	EFFICIENCY (% OF NORMAL)
Ad libitum	Normal	30	100
Ad libitum	Active	32	94
Ad libitum	Inactive	39	77
73 % of Ad libitum	Active	27	111
73 % of Ad libitum	Inactive	54	56
49 % of Ad. libitum	Active	36	83
49 % of Ad libitum	Inactive	77	39
33 % of Ad libitum	Active	46	65

(taken from Viteri et al.)

Since early malnutrition may result in suboptimal functioning at later ages, it appears important to consider that food is something more than nutrients and energy, and that feeding is something more than the ingestion of nutrients and energy. Within the context of the human species, food and feeding play a role along several dimensions. The first one, which may be called a physiological dimension, has as a unit of measurement the nutrient. Its function is to provide chemical substances to the organism for growth, maintenance and metabolic regulation.

The second dimension of food is psychophysical. Its unit of measurement would be the foodstuff, which through its organoleptic characteristics provide the organism with a variety of stimuli such as texture, color, aroma, flavor and temperature. In this context, a foodstuff presented at the table as two different kitchen preparations having the same nutrient and caloric value would appear as if two different foods were offered to the individual.

Finally, the third food dimension is psychosocial. Its unit of measurement would be the meal time. The functions of food in this context are, on one hand, to aid in symbol formation through the value family and society attach to food as a form of reward or punishment, as an identifying characteristic of an ethnic or subcultural group and so on. On the other hand, the meal time provides opportunities to demonstrate, clarify and practice role and status at the family and at the community level. Who is waited on first? Who sits at the place of honor at the table? Who is served the choice bits?

It seems easy to visualize that food deprivation in infants and young children represents not only a shortage of nutrients necessary for the increase in body mass but also a deprivation of sensory stimuli and of social experiences. Is it surprising that children who suffered food deprivation in early life show at later ages a lower mental, physical and social performance. Deprivation of food becomes automatically for the young child deprivation of chemical substances and deprivation of sensory and social stimuli.

With all the above information in mind, we have attempted to evaluate the effect of added stimulation during the rehabilitation from malnutrition suffered at a very early age. We have studied 36 severely malnourished children, all less than six months of age at the time of admission to a nutrition ward.[39] When admitted, all the children showed signs of deceleration of growth and development with weights and heights comparable to those of a normal newborn or at the most to a child two months of age. The level of development in the less severe cases was estimated as equivalent to 50 percent of the mean expected for that age. Immediately after all infectious processes and acute electrolytic disturbances had been corrected, the children were randomly divided into two groups: one with systematic stimulation and another without added stimulation. The behavioral development of both groups was evaluated periodically. The initial design of the study included only two groups of children, one with a program of systematic cognoscitive, emotional and language stimulation and another without stimulation beyond the one found in a normal hospital ward. It became apparent later, however, that some children in the latter group instead of showing apathy, lack of movements and expression characteristics of severe malnutrition, were active, smiled and often demanded, through facial expressions and movements of their hands and bodies, interaction with anybody who was nearby. The ward personnel could not resist the charm of these children, who, for this reason, received more stimulation although not in a systematic fashion nor for specific types of behavior, than the children "without stimulation." We decided to call this third group self-stimulated to emphasize the fact that the children by themselves started this interaction.

The program of systematic stimulation included the following aspects: first, learning of a reproducible model of mother-child interaction by a psychologist and the nurses of the day and afternoon shifts in the ward. This model is based on the scales proposed by Ainsworth, Bell and Stayton to evaluate the mother-child transactions during the first year of life.

Second, the microenvironment of the stimulated children was made up to give a high score when evaluated with the home stimulation inventory designed by Betty Caldwell.

Third, based on the record of performance of

each child in the Gesell and Uzgiris-McHunt developmental scales a program of individual stimulation in which the psychologist and nurses acted as substitute mothers, inducing the child to acquire the next step in behavior in each of the different scales.

Fourth, the only reward given to the children and the personnel was social reinforcement. Undesirable behavior was not reinforced.

In order to express the improvement in performance over the nutrition rehabilitation period, data for each child were plotted against days in the program. The shape of the curves suggested that the relationships could be represented by a series of linear functions. Data were therefore fitted to algebraic expressions of the form $Y = a + bx$. In this equation Y represents the performance calculated as days of specific behavior, i.e., the age at which a normal infant would give the score obtained in the tested infant; x is the number of days in the program, and the terms a (intercept) and b (slope of the curve) are empirical constants determined by the data. The constant b was estimated by the least-squares method for each group of infants and for each field of behavior, and represents the increment of performance over time.

As may be seen in Table 4, the slopes in all four developmental areas studied were systematically greater than 1.0 in the stimulated group and less than 1.0 in the non-stimulated group. The self-stimulated infants placed at an intermediate level with slopes greater than 1.0 (catching-up) in the motor, adaptive and social-personal behaviors. In language skills these infants did not attain catch-up values.

The distribution of the slope values obtained during nutrition rehabilitation is presented in Figures 3 to 6. It may be noticed that in each area of behavior studied the stimulated group had the greatest proportion of catch-up cases, the non-stimulated group had the lowest proportion and the self-stimulated infants had close to but above the non-stimulated group. It is interesting that for psychomotor development the self-stimulated group performed at the same level as the stimulated group, while for language development the proportion of self-stimulated infants who were catching-up (slopes greater than 1.0) was as small as that obtained in infants not systematically stimulated.

The results indicate that the addition to the dietary management of a program of systematic stimulation given within the context of a good mother-child interaction brings the majority of nutritionally rehabilitated infants, seven to nine out of every ten, back to normal, age-expected levels of performance on the Gesell Scales of Development. As a contrast, only three of every ten infants who received the dietary and medical treatment without systematic stimulation reached the levels of performance accepted as normal.

Preliminary follow-up data on these children indicate that those infants whose mothers learned to carry on the program of systematic

TABLE 4

MEAN VALUES OF SLOPES FOR THE REGRESSION MENTAL DEVELOPMENT (DAYS EQUIVALENT) AND DAYS OF TREATMENT, OBTAINED IN INFANTS LESS THAN SIX MONTHS OF AGE RECOVERING FROM SEVERE MALNUTRITION.

GROUP	MOTOR	ADAPTIVE	LANGUAGE	SOCIAL-PERSONAL
Stimulated	1.20 ± 0.24	1.22 ± 0.26	1.12 ± 0.19	1.19 ± 0.24
Self-Stimulated	1.15 ± 0.12	1.14 ± 0.24	0.97 ± 0.10	1.12 ± 0.17
Non-Stimulated	0.83 ± 0.22	0.79 ± 0.22	0.80 ± 0.24	0.78 ± 0.19

Figure 3

DISTRIBUTION OF SLOPE VALUES OF MOTOR DEVELOPMENT/DAYS OF TREATMENT OF INFANTS AGED LESS THAN SIX MONTHS RECEIVING OR NOT SYSTEMATIC STIMULATION DURING RECOVERY FROM SEVERE MALNUTRITION.

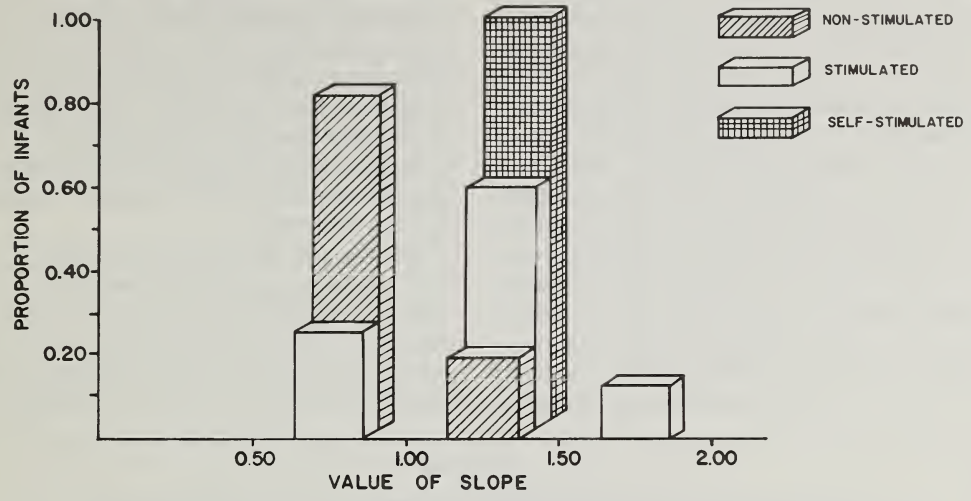
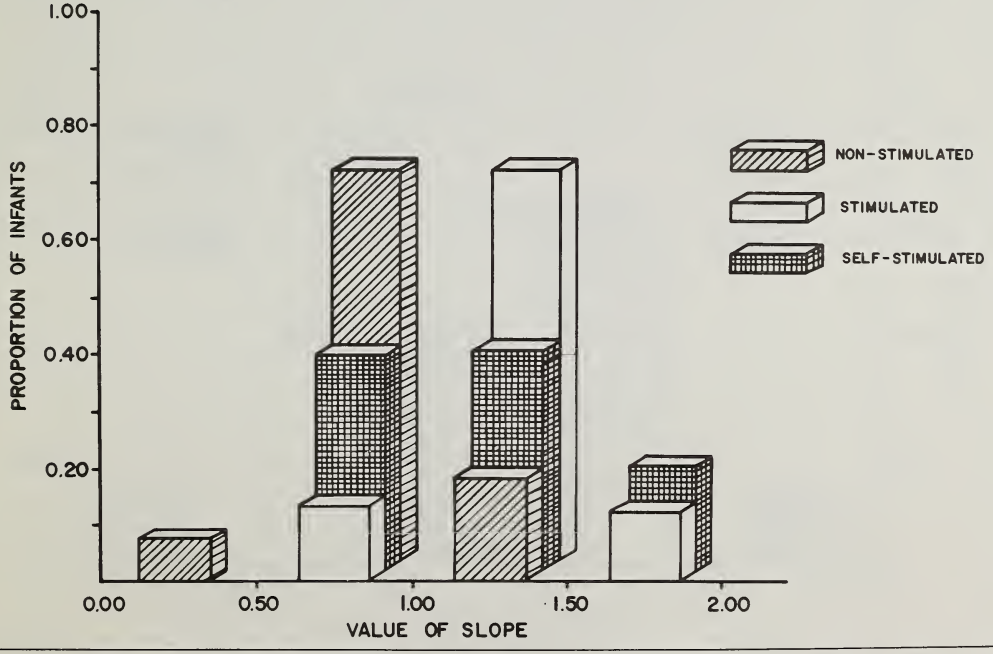


Figure 4

DISTRIBUTION OF SLOPE VALUES OF ADAPTIVE DEVELOPMENT/ DAYS OF TREATMENT OF INFANTS AGED LESS THAN SIX MONTHS RECEIVING OR NOT SYSTEMATIC STIMULATION DURING RECOVERY FROM SEVERE MAL-NUTRITION.



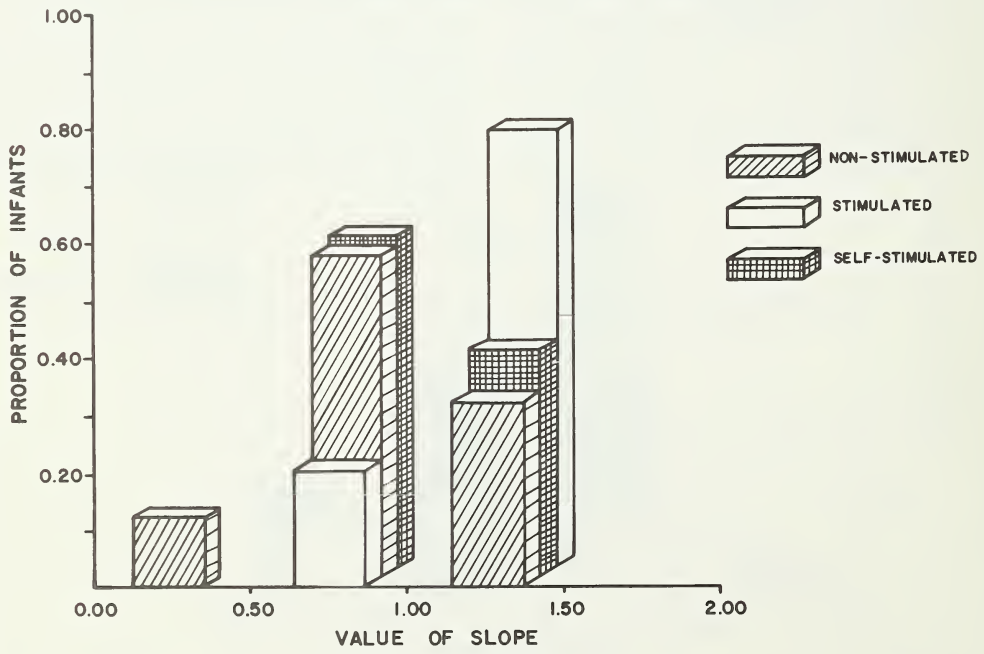
stimulation at home, and whose attitudes were changed in order for them to take an active, engaging and satisfying interactive role with their infants, have continued to present normal performance levels at each age tested. Mental scores and physical measurements appear to be independent of whether or not stimulation was provided during their hospital stay.

The study by Yatkin and McLaren[40] was also related to the effect of added stimulation during initial recovery. Two groups of severely malnourished children were evaluated during recovery with the Griffith's scale. One of these groups, paired by age and sex, was placed in an environment with paintings, drawings, toys and music, and in which the nurses played and sang with the children establishing affective relationships. The non-stimulated group remained in a ward of similar size but without colors, toys or music. The medical and dietetic treatment was the same for both groups. The initial difference in mental development was not significantly different. With treatment, both groups increased their levels of mental performance in a significant and almost parallel way. Only at the end of the observation period of four months did the stimulated group show more elevated quotients, mostly due to a low level of performance in the non-stimulated group. Both groups remained with values much lower than expected for their age with the interesting finding that, as with the Mexican children, the biggest deficit occurred in the area of language and communication.

Three to four years after discharge from the hospital, the children were re-examined. Two more groups were included to compare the mental performance of the children with and without stimulation with their healthy siblings and with another control group of healthy chil-

Figure 5

DISTRIBUTION OF SLOPE VALUES OF LANGUAGE DEVELOPMENT / DAYS OF TREATMENT OF INFANTS AGED LESS THAN SIX MONTHS RECEIVING OR NOT SYSTEMATIC STIMULATION DURING RECOVERY FROM SEVERE CLINICAL MALNUTRITION.



dren of the same low socio-economic class.

Mental performance was measured with the Stanford-Binet intelligence test. The children who recovered from malnutrition showed significantly lower intellectual quotients than their siblings and healthy children of the same social class. The children who had received stimulation during the period of hospitalization had lower levels of performance than the group without stimulation. McLaren et al. considered that this low performance of the children previously stimulated could be related to their belonging to the lowest socioeconomic conditions.

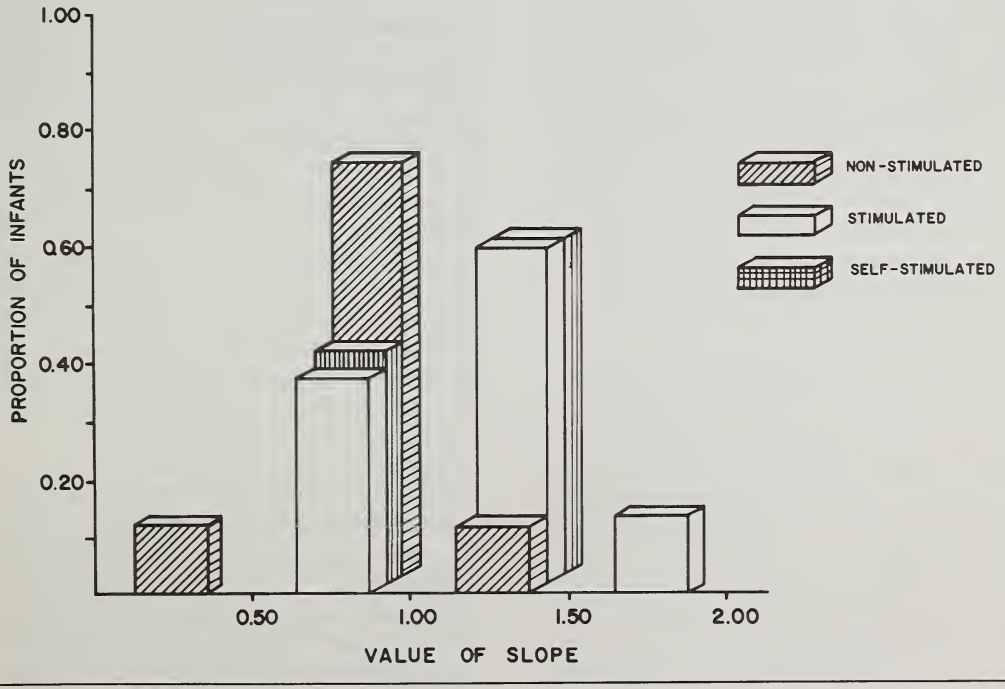
By including in their study a fifth group of children with malnutrition not severe enough to require hospitalization, these authors found that admittance to hospital plays a minimal part in the reduction of mental performance during malnutrition.

In children recovered from malnutrition, Klein et al.[41] reported that the level of prediction of the cognoscitive function given by sociocultural factors, such as quality of the home, formal education of the father, dress and personal cleanliness of the mother, instruction in tasks and social behavior can significantly increase with the inclusion of body weight and head circumference.

Similarly, Richardson[42] found that Jamaican children of school-age that had suffered severe protein-calorie malnutrition in infancy showed a correlation between their intellectual quotients, at the time of the acute episode of severe malnutrition, with height at the time of evaluation of intelligence and with the socioeconomical conditions of the child. The percentage of explained variance was greater for the social variables and lower for the episode of acute malnutrition. Body size gave an intermediate value.

Figure 6

DISTRIBUTION OF SLOPE VALUES OF SOCIAL-PERSONAL DEVELOPMENT/DAYS OF TREATMENT OF INFANTS AGED LESS THAN SIX MONTHS RECEIVING OR NOT SYSTEMATIC STIMULATION DURING RECOVERY FROM SEVERE MALNUTRITION.



In testing for the influence of the social environment independently of the possible influence of malnutrition per se the results of studies of upper and middle-class individuals who have suffered secondary malnutrition due to congenital pyloric stenosis or cystic fibrosis seem relevant.

Klein, Forber and Nader[43] studied fifty children (44 boys and six girls, aged between five and 14 years who had been treated for congenital pyloric stenosis) and found a significant negative correlation between the degree of severity of the starvation period, present at birth or in the first three months of life, and the intellectual performance measured by the Peabody Test and the Raven's Progressive Matrices Test ($r = -0.323$, $p < 0.05$). The severity of lack of food intake was estimated as a percentage of the difference between the weight of the child when admitted to the hospital and the expected weight for age extrapolated from the birth weight. Severity of starvation and a measure of the parental estimation of the child's intellectual development and expected educational potential also were negatively associated at a level of statistical confidence at 0.01. Global intelligence did not show consistent difference among the index cases, a group of siblings and a control group of 50 children matched with the index cases for sex and father's level of education.

The height of a group of Swedish adults who had suffered from pyloric stenosis between the ages of six to twenty days showed a significant correlation with the weight loss and the duration of the episode of starvation in early life. Performance on an intelligence test administered at the time of induction to military service did not correlate with the antecedent of neonatal malnutrition.[44]

The finding that individuals who experience nutritional deprivation confined to a short period of time at the beginning of postnatal life do not show detectable lower mental performance in later ages than their mates without the malnutrition antecedent is in agreement with the report of DeLicardie et al.[45] that mild moderate weight loss occurring only in the neonatal period affected body size but not mental performance, at least during the first years of life.

The mental performance, sensorimotor abilities and social adaptation of a group of 41 patients with ages from two to 21 years were studied by Still et al.[46] These patients had suffered severe malnutrition in the first six months of life. Thirty-four had cystic fibrosis, three had suffered ileal atresia and four others intractable diarrhea. None of these patients had evidence of socioeconomic deprivation. When the intellectual performance of this group was evaluated at 18 to 72 months of age with the Merril-Palmer test, the scores were significantly lower than those found in a group of siblings of similar age. In patients older than five years of age, the mean intellectual quotient in the WISC of WAIS tests did not differ significantly between the index cases and the controls. Neither motor abilities nor social adaptation measured with the Lincoln-Oseretzky Test and Vineland's Scale respectively, gave significantly different results between the patients and their siblings.

Winick et al.[47] have reported the effect of an enriched environment due to early adoption in three groups of Korean children before the age of three, fostered by North American families. Group 1 consisted of children whose weights and heights at the time of adoption were below the third percentile for normal Koreans. Group 2, called "moderately nourished" consisted of children with weights and heights between the third and twenty-fifth percentiles. Children above the twenty-fifth percentile formed Group 3. Children in this group were considered "well-nourished" of controls. After a period of four to 13 years new data on weight, height, intellectual quotient and educational achievements were investigated.

No differences were found in the weights of these three groups of children. The heights, albeit, were significantly lower in the group of malnourished children than in controls, but no differences were found between the latter group and the heights of the "moderately nourished" group.

This same pattern was found for the mental quotients and achievement scores, with the added finding of a significant difference in the achievement scores of the malnourished and the "moderately nourished" groups. It seems worthwhile to mention that the intellectual quotients and achievement scores in the three groups of children gave values similar or above

those found for average North American children. In a similar way, the three groups had weights on the average above the fiftieth percentile of the Korean standards.

These findings show than an enriched environment can minimize or nullify the effects of early deprivation. Perhaps equally important is the finding that the levels of performance and achievement of children who suffered deprivation at early ages are lower than those of children who did not suffer deprivations, even if all values are within the normal limits of an affluent population.

In regard to the mechanism of action of stimulation, Barnes and co-workers speak of an interaction between malnutrition and environmental stimulation.[48-52] They have considered that the physiological mechanisms that might be responsible for beneficial long term effects of early stimulation are not operational if they coincide with concurrent malnutrition during a critical period of development. Malnutrition would then change perceptual experience of the environment making the animal less able to receive and/or integrate information about the environment. Even in the absence of biochemical alterations of the brain, malnutrition might give rise to a behavior that is incompatible with the incorporation of environmental information necessary for an optimal cognoscitive development. Behavior expressed as apathy and social isolation are two examples of conduct frequently shown by human beings who have survived early malnutrition.

Recently, Morgan and Winick[53] have reported that rats stimulated early during the first three weeks of life have smaller behavioral changes caused by malnutrition 21 days postnatally. Most of the behavioral changes are associated significantly with increased levels of gangliosides and N-acetylneuraminic acid in the cerebrum and cerebellum. After six months of nutritional rehabilitation, early stimulation continues to be associated with better performance in a Y-type labyrinth. The biochemical changes of the brain persist until adult life.

Searching for the importance of these biochemical findings, in a second study Morgan and Winick[54] injected N-acetylneuraminic acid, (NANA) into the offspring of these rats while a control group received only glucose injections. The administration of NANA was associated with an increase in the amount of gangliosides in the cerebrum and cerebellum, along with an increase in the concentration of NANA. The animals also showed a reduction in the expected behavioral anomalies developed in these animals during the first three weeks of life caused by malnutrition. After six months of nutritional rehabilitation, the rats treated with NANA between 14 and 21 days of life learned to solve a Y-type labyrinth more quickly than the controls while the biochemical changes in the brain persisted. These results reinforce the possibility that early malnutrition can affect behavior through the concentrations of NANA.

Similarities in the biochemical changes in the brain produced by malnutrition or by stimuli deprivation found by Castilla et al.,[55] are of the utmost importance since they lead to the consideration that none of these two factors per se plays the most important role in the alterations of human development found in malnourished communities.

As Dobbing[56] has emphasized, the human being has the capacity to compensate one disadvantage with an advantage in another direction. The fundamental question for future studies in the field of nutrition, mental development, learning and behavior must be focused on the documentation and description of the mechanisms of nutrition per se or together with other unfavorable factors of the environment in which malnutrition flourishes.

Fortunately, the study of malnutrition as a possible cause of suboptimal mental development has shifted from the simplistic intent of considering the nutritional factor as the only cause of the low performance and distorted behavior shown by survivors of malnutrition. At present, the effort of most researchers is directed toward the quantification of the various factors in interactive combinations, in order to obtain a clearer perspective of the role played by each factor and their eventual control through appropriate intervention.

The findings of all the studies mentioned show the importance of non-nutritional variables to promote better development of children living under conditions of deprivation, and the necessity to transform these findings into techniques to be included in community pro-

grams, with the main objective of providing systematic stimulation to infants at high risk of developing severe malnutrition, diminishing the negative effects on mental development and performance caused by this syndrome. Intervention through a non-nutritional variable can help to provide families and communities where malnutrition is highly prevalent with an alternative for the protection of the intellectual equipment of children living in a marginal economy that is very difficult to change under the present circumstances of social inequality.

One aspect of particular concern in our studies, vis a vis the aim of defining malnutrition in terms of the degree of impairment of biological function associated with distinct degrees of nutritional deficiency, has been the consideration of the particular brain functions or mechanisms which may be differentially affected by the nutritional insult. This consideration was based on our knowledge that injuries of the brain only rarely produce alterations in all functions. The rule is to have a gradient going from functions one hundred percent impaired to functions totally intact.

When the research design for the longitudinal study was established, it was decided that one of the strategies for this assessment would be the comparison of the rates of acquisition of certain functions among groups of children with different risks of malnutrition. The study of contrasting groups as a strategy for identifying determinants of behavior was based on the consideration that this research approach is the best naturalistic analog of the experimental method associated with the physical and chemical sciences. Studies of Kagan and Moss on sex differences,[57] Kohn on social class[58] and Caudill and Weinstein on cross-cultural comparisons[59] are examples of research where information obtained in contrasting groups was used to derive theoretical concepts associated with parental treatment and child behavior.

In this endeavor, we began the analysis by selecting the level of adequacy in the visual-kinesthetic and in the auditory-visual intersensory modalities as indicators of brain development. This takes into consideration that the emergence of complex adaptive capacities seems to be underlaid by the growth of increasing liaison and interdependence among the separate sense systems,[60-62] and that the basic mechanism involved in the formation of conditioned responses (i.e., primary learning) is probably the effective establishment and patterning of intersensory organization.[63-64] Another reason for using intersensory competence as an indicator of neurointegrative development stemmed from the work of Birch and Lefford.[65] They demonstrated that adequacy of intersensory interrelations improves in an age-specific manner, giving developmental curves as regular as those obtained for age and weight, or age and length.

Visual-kinesthetic competence was explored by a method of equivalence in the perception of geometric forms. The kinesthetic sense modality used was the sensory input obtained through passive arm movements. Such motion entails sensory input from the wrist, elbow, and shoulder joints, and from the arm and shoulder muscles, as its principal components. In the test, kinesthetic information is provided by placing the child's preferred arm behind a screen, and, with the arm out of sight, moving it passively through a path tracing a geometric form.

The specific technique used for studying equivalent relationships among the visual and kinesthetic sense modalities was the recognition of geometrical forms. A paired comparison technique was utilized, a form presented to one sensory system was compared with equal and different forms randomly presented in another sensory system.

Auditory-visual integrative competence was measured as the ability to equate a temporally structured set of auditory stimuli with a spatially distributed set of visual ones. The specific demand made was the identification of a visual dot pattern that corresponded to the patterning of a rhythmic auditory stimulus. All subjects were tested individually in a quiet room, alone with the examiner. Judgments were scored right or wrong. No reinforcement was given.

The analysis of these two primary mechanisms underlying cognitive growth focused on a comparison of the levels of performance attained at successive ages (66, 73, 78, and 86 months) by the group of survivors of severe malnutrition and two groups of children select-

ed from the same birth cohort who were never diagnosed as severely malnourished. One comparison group was matched at birth for sex, gestational age, season of birth, body weight, total body length, and organization of the central nervous system as determined by the Gesell method. The second comparison group included children, full-term and healthy at delivery, who were matched for sex and total scores on home stimulation with the survivors of severe malnutrition. None of the other features of the macroenvironment, including per capita income, main source of income, percentage of total expenditures devoted to food procurement. and family size, nor the biological, educational, and health characteristics of the parents, was different in the three groups of children studied.

The mean number of errors in judging nonidentical forms presented simultaneously to the visual and kinesthetic sensory modalities decreased as the child matured, both in survivors of severe malnutrition and in controls for size at birth. The patterns of improvement in performance exhibited by both groups approximated the form of a growth function, with a marked difference in the value of the intercept and in the age at which asymptotic values were attained. The control group reached the asymptote by age 78 months, but it is not yet reached at age 86 months in the survivors of severe malnutrition.

Not only were mean number of errors greater in the survivors, the variability at all ages studied also was greater. Survivors of malnutrition performed at a significantly lower level of competence at all ages. The data clearly indicate the delay in development of intersensory organization present in these children from the first age studied.

For the development of auditory-visual intersensory integration, the level of competence also was markedly inferior for the survivors of severe malnutrition at all ages tested. For example at age 73 months, it was striking that not a single survivor made one correct judgment. On the other hand, the proportion of control children scoring higher than zero was three out of ten, with one of every ten controls reaching a five point score. At 78 months of age, six out of every ten survivors had scores of either zero or one correct response. The proportion of very poor performers in the control group was only three out of ten. This same pattern was observed when the children reached 86 months of age. The proportion of very poor performers (scores of zero or one) among the controls was about one-half of the proportion found in the survivors of severe malnutrition. At the other end of the distribution, not a single survivor gave more than four correct judgments and one of every ten control children reached a six to seven level.

The longitudinal data thus confirm the previous cross-sectional studies that suggested a delayed intersensory integration development in survivors from severe clinical performances at ages 73 and 78 months who were selected for analysis of the kinesthetic-visual task, comparing children with and without antecedents of severe clinical malnutrition matched for scores on total home stimulation.

Taking a cut-off point at 25 errors, Table 5 shows the proportion of children attaining this or a lower value. As may be seen, there is a clear gradient of competence among the three groups of children, with the controls for size at birth placed at the highest level, the malnourished at the bottom, and the children matched for home stimulation with the survivors at an intermediate level of competence. A Chi-Square Test of proportions indicates that these figures are significantly different at the 0.05 level of statistical confidence.

At 78 months of age, if one takes a cut-off point at 16 errors, survivors of malnutrition, controls for home stimulation, and controls for size at birth exhibit a gradient of performance in kinesthetic-visual ability similar to that seen for the 73-month-old group. Children without antecedents of severe malnutrition and with higher scores on home stimulation placed first, followed by children without antecedents of malnutrition, and, finally, by the survivors of malnutrition who are malnourished.

As was mentioned above, survivors of severe malnutrition and controls differed not only in the nutritional antecedent, but also in the amount and quality of the stimulation available in their homes. Thus the antecedent of severe malnutrition was significantly associated with diminished home stimulation. Survivors of se-

TABLE 5

Proportions of 73-Month-Old Children Showing 25 or Less Errors in Visual-Kinesthetic Competence.

("Land of the White Dust")

GROUPS	PROPORTION OF CHILDREN WITH $\leq$ 25 ERRORS	
MALNOUR	0.529	5 of 10
SIMSTIM	0.823	8 of 10
SIMSIZE	1.000	10 of 10

X^2 PROPORTIONS= 28.87; Df=2; $P < 0.05$

(MALNOUR + SIMSTIM) VS. SIMSIZE= 8.51; Df=1; $P < 0.05$

MALNOUR VS. SIMSTIM= 20.36; Df=1; $P < 0.05$

vere malnutrition showed a significant delay in both kinesthetic-visual and auditory-visual competences. It seemed logical, therefore to try to separate the possible effects of the nutritional and the non-nutritional variable. Our attempt to do so was through the inclusion of a control group of children who never were diagnosed as suffering from severe malnutrition, but whose total scores on home stimulation were equal to the scores of the survivors, both before and after the episode of severe clinical malnutrition.

In considering errors, it is clear that, for growth functions, the examination of group differences can best be explored after the period of chance performance and before performance reaches the asymptotic level when the function has completed its growth and does not increase with age. Accordingly, the differences among the three groups of worst performers are statistically significant at the level of confidence of 0.05.

The picture for the development of auditory-visual intersensory integration is markedly different from that obtained for the kinesthetic-visual task when survivors of severe malnutrition are compared with children having the same low scores on home stimulation but without the antecedent of malnutrition.

At all ages considered, Chi-Square tests of proportions make evident the lack of difference between children with and without antecedents of severe malnutrition matched for total scores on home stimulation (Table 6).

The results of the previous cross-sectional studies on kinesthetic-visual intersensory integration are thus in agreement with our data from the longitudinal study. The antecedent of severe malnutrition independent of the characteristics of the stimulation available at home is strongly associated with the levels of competence in the kinesthetic-visual task. Since the quality and quantity of the stimulation available at home also showed a significant correlation

TABLE 6

AUDITORY - VISUAL INTEGRATION PROPORTION OF CHILDREN MAKING NOT LESS THAN 4 CORRECT JUDGMENTS AT 78 MONTHS AGE.

("LAND OF THE WHITE DUST")

GROUPS	PROPORTION OF CHILDREN WITH 4 OR MORE CORRECT JUDGMENTS.	
MALNOUR	0.277	3 of 10
SIMSIZE	0.666	6 of 10
SIMSTIM	0.176	2 of 10

X^2 PROPORTIONS = 10.95; Df= 2; $P < 0.05$

(MALNOUR + SIMSTIM) VS. SIMSIZE = 10.55; Df=1; $P < 0.05$

MALNOUR VS. SIMSTIM = 0.40; Df=1; $P > 0.05$

with the intersensory task, the developmental lag observed in survivors of malnutrition appears to be the result of the effects of earlier malnutrition in association with certain microenvironmental factors related to child care.

The findings in relation to auditory-visual integration give a totally different picture. When the difference in home stimulation between survivors of severe malnutrition and control children was cancelled out, the performance of the survivors was at the same level observed in control children with low scores in stimulation. The disappearance of the developmental lag in the survivors points to a strong association between stimulation available in the home and competence in auditory-visual integration and to a lack of association between a previous history of severe malnutrition and auditory-visual competence.

The importance of sorting out specific mental abilities as a function of macro and micro environmental factors that would exert a more powerful influence on them is obvious from both practical and theoretical viewpoints. From the nutritional side, the planner and the policy-maker must know what to expect in terms of both prevention and rehabilitation of mental sequelae to be accomplished by intervention programs.

The past 20 years have witnessed our efforts to answer some pragmatic questions. The first has been our contribution to document that decelerations in physical growth and biochemical composition are associated with lags in mental development in survivors of severe malnutrition. The second, that by modification of non-nutritional variables plus correction of the nutritional deficiency, the mental lags found in survivors of severe clinical malnutrition, even when suffered at an early age (before six months of age) and of long duration, two-thirds or more of the life of the infant, are reversible. And third, that some basic neurointegrative functions, related to primary learning, and to the acquisiton of basic academic skills such as reading and writing, are differentially modulated in their development. Nutrition plays a major role in some brain functions and stimulation is

the main influence in another set of functions.

It has taken us 20 years to come to our present situation in tackling the problem of malnutrition, mental development, learning and behavior. From studies of the child we have moved to epidemiological considerations about the agent, the host and the environment, particularly the microenvironment. We are beginning to tease out the different outcomes related to nutritional insult either along or in combination with other non-nutritional components of the environment of the malnourished child. Finally, we are just moving into the problem of scientifically defining the points in the developmental sequence at which quantitative estimated levels of nutritional deficiency may interfere with emerging functions to give either delayed or disordered development.

Twenty years is quite a bit of time, "If somebody believes that acquisition of knowledge is expensive, ask him/her to think about the cost of ignorance."

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